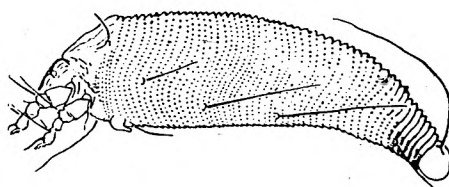


ENTOMOLOGICAL RESEARCH : TRENDS, CHALLENGES AND OPPORTUNITIES

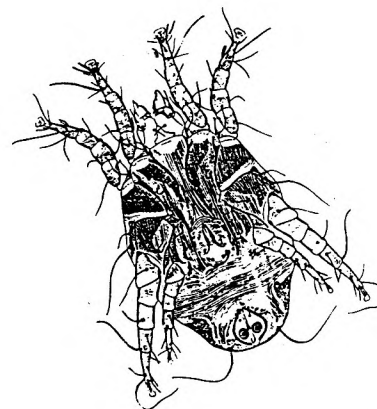
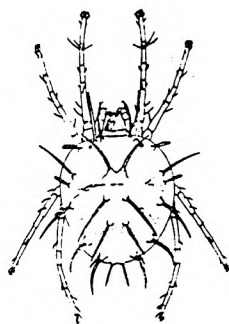
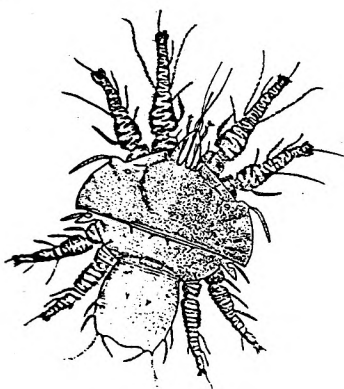
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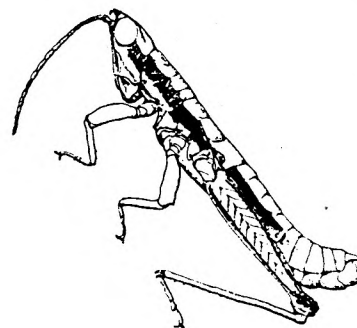
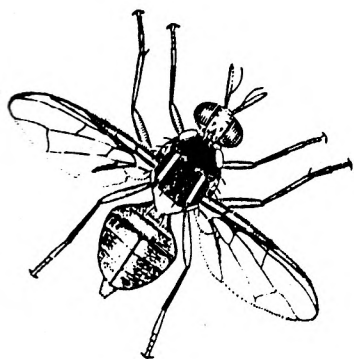
A Tribute

to

Prof. G. P. Channa Basavanna



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8/9/2000

ENTOMOLOGICAL RESEARCH : TRENDS, CHALLENGES AND OPPORTUNITIES

8 September, 2000

A Tribute

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Our Beloved GPC

*The insect world knows you GPC
Little of this world knew we GPC
Till we learnt from you GPC
Tell us more about it GPC*

*Mites, Bees and pest management
You gave us the full complement
That they are a participant
In this world environment*

*Soft spoken are you,
'Of courses' you add so many
Convincing with authority
You can win over many*

*To meet you was no problem
But for visitors infinitum
A patient hearing did you
Give us whenever we met you*

*Though you cherished best the mite
It was with all your might
You encouraged subjects alike
Without turning the Nelson's eye*

This ode was penned by Dr.S. Ramani on the retirement day of our beloved teacher Prof. G.P. ChannaBasavanna



Dr G. P. ChannaBasavanna
(1920 - 2000)

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PROF. G.P. CHANNABASAVANNA
1920 - 2000
LIFE AND WORKS

The growth of acarology in India during the last three decades can be attributed to a few landmark events: organisation of two training programmes and founding of Acarological Society of India in the seventies, organisation of VII International Congress of Acarology and implementation of the All India Coordinated Research Project on Agricultural Acarology by Indian Council of Agricultural Research (ICAR) in the eighties. One personality behind all these events was Dr G.P. ChannaBasavanna (GPC). In the seventies when very few biologists in this country were working on mites and ticks, the two training programmes organised by GPC were successful in guiding several young biologists of the time to get to know the basics of acarology, and many among them later took up the study of mites and teaching acarology at graduate level in different universities of the country.

The Acarological Society of India under the presidentship of GPC has published the works of several acarologists in this part of Asia in the Journal of Acarology (formerly Indian Journal of Acarology) and Acarology Newsletter which were edited by him. In addition, he organised five well-attended national symposia under the aegis of this Society. The International Executive Committee of Acarology Congress accepted GPC's proposal to host the VII International Congress of Acarology in India, in 1986 and for the first time an Acarology Congress was held outside Europe or America.

His wish of strengthening the acarological research in the country by establishing a network of acarologists was greatly achieved when the ICAR approved his proposal to set up the All India Coordinated Research Project (AICRP) on Agricultural Acarology with centres in eight universities spread across the country. Today this project has been conducting research on various aspects of plant-associated mites including taxonomy, ecology and management. GPC's main contribution was to our understanding of Eriophyidae (tiny four-legged mites frequenting flower and vegetative buds and many causing galls or erineae to which the recently invaded dreaded coconut mite belongs) and Tetranychidae (spider mites). In recognition of his contributions, four species of mites have been named in his honour: *Calacarus channabasavannae* Lakkundi 1974, *Amblyseius channabasavanni* Gupta 1978, *Typhlodromus (Orientiseius) channabasavanni* Gupta and Daniel 1978 and *Tuckerella channabasavanni* Mallik and Harish 1992.

As an agricultural scientist, he did not confine himself only to the plant mites but was almost the first one to initiate work on house dust mites in the country in early eighties, with visions of preparing allergens that can be used at very low dosage to desensitise humans sensitive to dust mite allergens.

From the above, one should not construe that GPC was interested only in acarological research. He should be viewed as a biologist interested in insects, rodents, birds, etc., but with slight inclination to acarines. His students and colleagues respected him for the extensive knowledge he possessed about various insect groups

both beneficial and harmful. Systematics was his most adored field, hence most of his students worked on taxonomy of various groups of insects and mites. It is for this reason that the Department of Entomology at Bangalore is identified with taxonomic research in the country.

Having realised the potential of exploitation of natural enemies in management of crop pests, he was a strong advocate of Integrated Pest Management throughout his career. As early as 1975, he initiated work on management of cabbage pests integrating information on pest load, weather parameters and plant age.

Among the entomologists of this state, Puttarudriah and ChannaBasavanna were almost household names during the middle of this century. Dr M. Puttarudriah who was a student of Dr Paul DeBach, was a strong opponent of modern pesticides whereas GPC was a moderate, proposing need based usage of pesticides. Both these personalities were shifted from the Mysore State Department of Agriculture to the Agricultural College at Hebbal to teach entomology for the degree students. The efforts they put in to develop the Department of Entomology is reflected by the fact that several of their students recollect the courses in entomology taught with devotion even to this day. If Puttarudriah's efforts to set high standards of teaching and research in entomology was reflected by the preference of many students to continue their studies in entomology, GPC's efforts in developing the department is reflected in widening its activities. During his tenure as the head of the Department of Entomology, he started the postgraduate courses in Sericulture for the first time in the country, he also initiated research on honey bees. His interest in honey bees was not confined to academic aspects. His efforts to popularise bee keeping resulted in starting of the Bangalore Bee-Keeper's Association of which he was the founder President.

Gulur Puttappa ChannaBasavanna or GPC as his students and colleagues fondly called him was born on September 8, 1920 to a modest family in Gulur, a small village at the time. His early schooling was at Gulur and at nearby Tumkur. In 1937, he came to Bangalore to obtain a degree in Zoology at Central College. He put in a brief period of service in the State Department of Agriculture, during this period his assignment was to visit coffee estates in the hills of Chikkamagalur and inspect the sanitation measures undertaken by the estates against the white stem borer. This job required that he moved between the estates on his bicycle and very often in unpleasant weather. In 1946, he started his career as a teacher when he was appointed a lecturer at the Hebbal Agricultural College near Bangalore. Between 1951 and 1953, he was away at Aligarh to complete his Master's degree programme on insect morphology under the tutelage of Dr Mashood Alam. Back in Bangalore, he was involved in teaching entomology and economic zoology to the undergraduate students and studying insects both pestiferous and beneficial ones. His pioneering works on ladybird beetles (Coccinellidae), areca mites, sorghum mites during this period are referred to even today. Later in 1960, he took up taxonomy of eriophyids for his doctoral degree programme at the Indian Agricultural Research Institute, New Delhi under the guidance of Dr Ramdas Menon. Being the first in this country to initiate taxonomic work on these tiny mites, he had to go through the tough experience of obtaining pertinent literature and a good microscope. His efforts are reflected in the bulletin "Contribution to the Knowledge of Indian Eriophyid Mites" which carries description of 70 species of eriophyid mites of which 44 were new to science and rest of the 26 were mostly described by workers elsewhere. In 1970, he took over the reins

of the Department of Entomology from Puttarudriah who had been elevated as the Director of Instruction (Agriculture). During the ten-year period as Head, the developments in the department were remarkable. An UNDP funded project was in operation, which provided an opportunity for GPC and other staff to obtain training abroad, the sericulture graduate programme was started, apiculture research was strengthened, an All India Multi-location Project on mites was initiated, similarly research on rodents was given a boost, a project on house dust mites funded by the Department of Science and Technology, New Delhi, was initiated. It is worthwhile to note that GPC was even guiding doctoral students of surrounding universities. After retirement in 1980, he was designated as Professor (Emeritus) by ICAR till 1985. During later years, he kept his interest alive as a visiting professor of Entomology and more so as the Chief Advisor of AICRP (Agricultural Acarology) and Indo-Dutch project on Uji fly management.

His energy knew no bounds. He was disappointed his health did not permit him to participate in the workshop of AICRP (Agricultural Acarology) this April, organised at Kalyani. He had unfailingly participated in all the workshops of the above project in the past, and invariably sat through all the papers presented during the five national symposia on Acarology, organised by the Acarological Society of India. He had extensively toured in Europe, USA, Japan and the Philippines. He participated in the III -VI International Congresses of Acarology and had chaired sessions at the sixth and seventh Congresses.

His technical expertise in entomology was sought by many organisations. For several years he served on the Entomology/Nematology Scientific Panel of the ICAR. He was chairman and member of several quinquennial review teams (QRT) set up by the ICAR to review the research in various Institutes and Projects. As a member of the Editorial Board of the Indian Journal of Entomology, Indian Journal of Sericulture and Mysore Journal of Agricultural Sciences, he was largely responsible for maintaining high standards of these journals.

In recognition of his life time contributions to growth of entomology and acarology he was conferred the "Rajyotsava Award" by the Government of Karnataka in 1992 and was recognised as "Emeritus Acarologist" by the Acarological Society of India during Silver Jubilee Symposium of the Society in 1999.

GPC will be remembered by the students of science through his more than 200 publications on entomology, acarology, sericulture, apiculture and three books on agricultural entomology and acarology. After a brief illness GPC died on May 1, 2000. He is survived by his wife, three sons and six grand children.

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DR. R. S. PARODA
SECRETARY
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भारतीय कृषि अनुसंधान परिषद्
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D.O. No. SECY. (DARE)/DG, ICAR/2000
May 11, 2000

Dear Dr. Mallik,

I am shocked to learn about the sad demise of Dr. G.P. ChannaBasavanna, Chief Adviser of the AICRP on Agricultural Acarology on the 1st May, 2000. Please accept my heart-felt condolences. I pray to the Almighty for peace to the departed soul and strength to the bereaved family members to bear this irreparable loss.

With kind regards,

Yours sincerely,

(R.S. PARODA)

Dr. B. Mallik,
Project Coordinator,
All India Co-ordinated Research Project on
Agricultural acarology,
College of BS & H Building,
University of Agricultural Sciences,
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Krishi Bhawan, Dr. Rajendra Prasad Road, New Delhi-110 001

D.O. No. PA/DDG(CS)/2000/275
Date : May 10, 2000

Dear Dr. Mallik,

We, the crops scientists' of the Indian Council of Agricultural Research are shocked to learn the untimely demise of Dr. G.P. Channa Basavanna who indeed contributed enormously for the cause of agricultural research and development in general and acarology in particular. We pray to the Almighty to provide peace to the departed soul in the Heaven and strength to the bereaved family to bear the loss with fortitude.

Kindly convey our condolence to the bereaved family.

With regards,

Yours sincerely,


(MANGALA RAI)

Dr. B. Mallik,
Project Coordinator,
All India Coordinated Research Project on
Agricultural Acarology,
College of BS & H Building,
University of Agricultural Sciences,
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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
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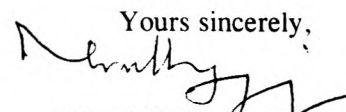
Dated: May 10, 2000

No. PA-ADG (ESM) 2000

Dear Dr. Mallik,

It is very shocking to know the sad and untimely demise of Dr. G.P. Channa Basavanna. It is an irreparable loss to the institute and to the students like us who have immensely benefitted from him. I pray the departed soul rest in peace.

With kind regards,

Yours sincerely,

(MRUTHYUNJAYA)

Dr. B. Mallik,
All India Co-ordinated Research Project on Agricultural Acarology,
UAS,
GKVK, Bangalore-560 065.

MY REMINISCENCES OF GPC

Dr. B.K. Nagesh Chandra, D.I. (Seri.), UAS, Chintamani

I had the privilege of close association with Dr. GPC since 1967 as his P.G. student. Then on my association with him continued till he lived. It is a pleasant experience to recall the various events and the time spent with him. He has played a key role in molding the career of several of his fortunate students of whom I am also one.

I always admired his work culture, and communication skills in teaching. He was adept in conveying to students any tough subject in a simple and easily understandable language. Dr. GPC was always punctual and very meticulous in carrying out the work. It has been my experience that even after his retirement we are unable to cope up to his expectations particularly with reference to correction of the research manuscripts. Which we would request him to go through and offer suggestions. Dr. GPC is role of model not only as a devoted teacher, researcher, scientist and a visionary. It was during his period as HOD Entomology he developed the new areas of research viz., sericulture, apiculture rodent biology and acaralogy. Which have developed as independent departments and college. He was a very good field entomologist too. It was his persistent effort and field work at Ramanagaram taluk, Bangalore district solved the problem of ujifly menace and silkworms during the early periods of its introduction to Karnataka. The popular recommendation of netting the raring trays which help the farmers from the loss due to ujifly. He is a unique gifted personality combined with all the virtues one can imagine. He was always engaged in some kind of task either writing or reading.

I admit, we his student, had no courage to talk to him any thing other than the subject matter. Perhaps he is the only professor of UAS who actively attended scientific work by guiding, and regularly visiting the universities even 20 years after his retirement. He knew only work, he never worked for wages, never aspired for any position. What ever we achieved it was only due to his merit. As an evidence to this he was left large number of his students and admirers. Dr. GPC will always remain evergreen for his students and admires as one and the only role model.



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D. O. No. 574
Dated. 15-5-24

Dear Dr.Malik,

We are deeply grieved to hear the sudden demise of Dr.G.P.ChannaBasavanna. Vacuum created with his demise can never be filled, especially in the field of Acarology. We the faculty and students of the Department of Zoology, Punjab Agricultural University, Ludhiana place on record the outstanding contributions of Dr.Channa Basavanna.as a scientist and a teacher and offer our heart felt condolences.

May the Almighty give strength and courage to his family members to bear this irreparable loss and may his soul rest in peace.

Head VKRane
Deptt.of Zoology 15/5

Dr.B.Malik,
Project Coordinator
College of BS&H Bldg.,
Univ.of Agricultural Sciences,
GKVK, Bangalore.560065.



ગુજરાત કૃષિ યુનિવર્સિટી
GUJARAT AGRICULTURAL UNIVERSITY
Department of Entomology
NAVSARI CAMPUS 396 450

NO.ACN/AICRP-AA/145
Navsari ,

Dated : 18 / 05 / 2000

#1321

18 MAY 2000

To,
Dr. B. Mallik,
The Project Co-ordinator (acting)
AICRP on Agril. Acarology,
College of BS & H Building,
University of Agril. Sciences,
G K V K , Bangalore - 560 065.

Respected Sir,

We have learnt from your letter the sad demise of our chief advisor of the project, Dr. G.P. ChannaBasavanna Saheb on 1st May, 2000. We all, GAU family members, feel deep sense of sorrow. He was eminent Acarologist and was pioneer scientist in Acarological Research in India. We met him during the last silver jubilee symposium of Acarological society of India held at Bangalore during October 27 - 30, 1999. He left behind the great memories to all the participants. He was very kind hearted, generous and Co-operative to extend his support to all of us.

We extend our deep sense of sorrow and pray to almighty God may give him deep peace to his soul and strengthen his family members to bear this happenings .

Kindly convey our message to his family members.

Yours sincerely ,

I/c. Professor and Head
Department of Entomology,
N. M. College of Agriculture,
Gujarat Agril. University,
Navsari Campus Navsari-396 450.

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From

Dr. S. K. Gupta
Flat No. 1C/10.
Anandam Housing Complex
F K. B. Saram
Calcutta - 700080

May 9, 2000

Dear Dr Mallek,

I was terribly shocked receiving the news ^{on May 8, 2000} of the sad and sudden demise of Prof Channabasavanna on May 1, 2000.

When I saw him last at Bangalore during Acarology Symposium, he was so hale and hearty that none could think of that that same was his last Acarology Symposium.

Sometimes it is becoming difficult for me to believe that if I go to Bangalore, he will be no more there to give an affectionate patting on the back and receive with his usual smile. Indeed, it ~~will~~ is an irreparable loss to all of us in general and to the science of Acarology in India in particular. I wish and

pray to the God to give him eternal peace. Last year, I lost my father and this year I have lost another very dear person of mine like "GPC" who is behind bringing me at the place where I am now at the moment.

I will never forget his helping hands which I received from him ~~during~~ since I came in contact with him.

I have already sent a condolence telegram ~~to~~ his family members.

I have received your earlier letter and convey my sincere thanks to you for inviting me at your Group Meeting.

Best regards & Wishes, Sincerely
to you and to my former colleagues. S. K. Gupta

GPC - A CONSUMMATE HUMAN BEING

Dr. G. P. ChannaBasavanna (fondly called GPC by his students and colleagues) belongs to that class and generation of scientists and teachers who have been exposed to working conditions in the field, laboratory and classrooms that call for ingenuity, perseverance, patience, and similar qualities and virtues that mould you into a wonderful human being first and a teacher and scientist later. With humble beginnings from a village near Tumkur and later armed with a degree in Zoology from Central College, Bangalore obtained in 1941 he began his career in the field of agriculture by joining the State Department of Agriculture in 1943 to work in the coffee estates in Chikkamagalur. His first job involved ensuring compliance of the Insect Pest Act against coffee white stem borer by the growers. Several years later he would still narrate with astute precision the arduous and long treks, the difficult terrains he had to traverse, the leech bites and the hard task of convincing the estate owners to take up pruning and BHC swabbing to control the pest. The wonderful world of insects that came under his view during this stint in the lush green western ghats prompted him to study them and that became his singular lifetime ambition. His first job in the company of insects came to be his lifetime love and fashioned him into a great entomologist.

His love for teaching and research drew him into the Agricultural College, Hebbal, Bangalore where he joined in 1946 as a lecturer and continued as Assistant Professor until 1966. During this period, his desire to equip himself better in the field of entomology took him to Aligarh Muslim University from where he completed his M.Sc. in 1953 specialising in insect morphology. The same desire also prompted him to start work on his Ph.D. from the Indian Agricultural Research Institute, New Delhi in 1960. Under the able guidance of Prof. M.G. Ramadas Menon he completed his doctoral dissertation on eriophyid mites of India. The fact that his doctoral thesis was published as a bulletin titled 'Contribution to the knowledge of Indian Eriophyid Mites' shows that the work was top-notch. The saga of his association with mites in particular and insects in general began with this.

GPC served as Associate Professor of Entomology from 1966-70 and took over from Dr. M. Puttarudriah as Professor and Head of the Department of Entomology in 1970. A sample of the remarkable strides made by the department during his ten-year tenure include starting of post graduate programmes in sericulture, strengthening of research on apiculture, a DST funded project on house dust mites, strengthening of the research and teaching in entomology through a UNDP project on plant protection, initiation of a multi-location project in acarology, etc. His retirement in 1980 did not detract in any way from him serving the cause of entomology and helping in development of the department, that was so close to his heart. He continued to adorn the department as ICAR Emeritus Professor and Visiting Professor until 1985. He served as Chief Adviser to the All India Co-ordinated Project on Agricultural Acarology and Indo-Dutch project on Uzi fly management for a long time after his retirement. His continued visits to the department to help his colleagues and several students and his insatiable desire to be amongst the entomological fraternity is a glowing example of his love for the subject. His presence in the department during seminars, meetings and several functions of the Entomology Club used to bring a unique halo to the occasion. GPC's routine to visit the department regularly so long after his retirement (nearly twenty years) is hard to emulate by any other.

The Government of Karnataka Rajyotsava Award in 1992 for distinguished service to the cause of agriculture in Karnataka, recognition as 'Emeritus Acarologist' by the Acarological Society of India, chairing sessions in international and national congresses, serving as a member in several important committees, serving in the editorial board of several journals are some of the recognitions that came his way for his invaluable contributions. The students whom he has taught courses in Entomology, guided for M.Sc. and Ph.D., more than 200 research papers, three books and the aura he has left behind are the shining marks for all of us to cherish and remember.

As a person Dr. ChannaBasavanna was very genial, soft spoken and gentle. His knowledge and depth of the subject was exemplary. Many of us can recall his gentle probing questions in seminars and viva-voce examinations, which can be answered only by in-depth understanding of the subject. He would never get upset by wrong answers and would goad you through his distinctive style of further questioning until you came up with the answer. His forte was his coolness at all times and the ability to remain unperturbed even in crises. He was blessed with great stamina and energy and put that to good use. He was a stickler for precision and expected the same from all. He was very kind, generous, and affectionate to all. It will be most appropriate to call GPC a human being par excellence. The best tribute to him would be for us to emulate and cherish the virtues and the values he stood for.

S. Ramani - a student of GPC.

TRANSGENIC PLANTS FOR INSECT PEST MANAGEMENT: CURRENT STATUS AND PROSPECTS

T. M. MANJUNATH

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Transgenic plants are normal plants which carry the introduced gene(s) expressing the desired trait(s). Such traits may include insect resistance, disease resistance, herbicide tolerance, herbicide-cum-insect resistance, drought tolerance, quality traits, etc. Current global status and prospects of transgenic crops in general and insect-resistant crops in particular are outlined here.

The years 1996-1997 heralded a new era in plant protection as three insect-resistant transgenic crops expressing *Bt* (*Bacillus thuringiensis* - a soil bacterium) endotoxin genes were commercially introduced in the U.S.A. These were *Bt*-corn conferring resistance to European corn borer (*Ostrinia nubilalis*), *Bt*-potato to Colorado potato beetle (*Leptinotarsa decemlineata*) and *Bt*-cotton to tobacco budworm (*Heliothis virescens*) and bollworm (*Helicoverpa zea*). These crops have given significant benefits by way of effective pest management, higher yields, greater profits and safer environment through decreased use of conventional pesticides. Consequently, the area under transgenic crops has been increasing in the U.S.A. and these crops are also being grown in other countries Australia, Mexico, Argentina, China, Spain, France, Portugal, Rumania and Ukraine. The global area under insect-resistant transgenic crops which was 1.1 million hectares in 1996 increased to 4.0 m. ha in 1997, to 8.0 m. ha in 1998 and to 11.7 m. ha in 1999, thus showing more than 10-fold increase in about 3 years. Such adoption rates are unprecedented and are the highest for any new technologies in the agricultural sector.

In India also, transgenic technology has recently attracted considerable attention with *Bt*-cotton being in the forefront. Maharashtra Hybrid Seed Company (MAHYCO) has introduced Monsanto's 'Bollgard' *Bt*-gene into the Indian cotton hybrids by back-crossing with a transgenic line. These plants, conferring protection against the notorious Indian cotton bollworms (False American Bollworm - *Helicoverpa armigera*; Pink Bollworm - *Pectinophora gossypiella*; Spotted Bollworm - *Earias vittella*; and Spiny Bollworm - *E. insulana*), have undergone multi-location field trials in 1998 and 1999 under the supervision of Department of Biotechnology (DBT), Government of India. The Review Committee on Genetic Engineering (RCGM) under the Ministry of Environment and Forests, after scrutinizing the field data, has given approval in July 2000 for large scale field trials on 85 ha and seed production on 150 ha in different geographical locations in the country. This is the first transgenic crop ever to be given such approval in India. Experiments on insect-resistant transgenic plants like brinjal, cabbage, cauliflower, potato, rice, tobacco and tomato are also being carried out by IARI, various ICAR and other research institutions, universities, private companies etc. Insecticidal plants can be a major component of integrated pest management.

In addition to insect resistance, transgenic crops carrying other traits like herbicide tolerance, virus resistance, insect-cum-herbicide resistance, quality traits etc. have also been developed and increasingly grown in several countries with the USA (72%), Argentina (17%), Canada (10%) and China (1%) being very dominant. The total global area under all transgenic crops in 1999 was 39.9 m. ha of which 11.7 m. ha (29.0%) were insect resistant crops.

The global market for transgenic crop products has grown tremendously from year to year. The estimated global sale from transgenic crops was US \$ 75 million in 1995; it increased to \$ 235 m in 1996, to \$ 670 m in 1997, to \$ 1.6 billion in 1998 and to \$ 2.3 billion in 1999, thus showing about 30-fold increase in a short span of five years. The global market is projected to reach \$ 3 billion in 2000, \$8 billion in 2005 and \$ 25 billion in 2010. The number of countries growing transgenic crops has increased from 6 in 1996 to 9 in 1998, to 12 (8 industrial and 4 developing) in 1999. More countries are showing increasing interest in this technology.

In every country, the prescribed biosafety requirements are to be fulfilled before a transgenic technology is approved for commercialization. All the transgenic crops that have been commercialised so far have gone through and passed extensive safety trials with regard to toxicity, allergenicity, pollen transfer, safety to non-target beneficial organisms, etc. In India, DBT, through its various expert committees, is responsible to ensure compliance of the required biosafety regulations for all genetically modified organisms (GMOs) including transgenic plants.

Transgenic technology is highly precise and powerful. It is not a panacea, but has the potential to usher in the much-needed second 'green revolution' in the face of burgeoning population. Effective dissemination of correct information and proper guidance are necessary to remove any misconception or apprehension about this remarkable new technology.

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PEST MANAGEMENT IN PULSES – A CHALLENGE

S. LINGAPPA

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Pod damaging insects are a major threat to productivity and production in all the pulse growing areas in the country and South east Asia. Among the pulse crops, pigeon pea and chick pea cultivation, in economic terms, is only possible if the pod borer damage is contained. Returns from adoption of plant protection technology is higher than any other technology, in profitable cultivation of redgram and bengal gram.

Pigeon pea, king of pulses, is grown over an area of 25 million ha with a total production of 15 million tonnes at an average of 6 Qt/ha. Karnataka takes fifth position in area and sixth in production. North eastern Karnataka, comprising of Gulbarga and Bidar and two taluks of Bijapur district is referred as “**Pigeon pea bowl**” it contributes nearly 70% of the state's production.

Total loss caused by pod borers in pigeon pea is highest in south and central India and least in north India. In contrast, pod fly is dominating in north and central part and is less destructive in south. *Helicoverpa armigera* is a single pest that shakes the economy of North East region of the state. It breeds allround the year by feeding on 181 host plants comprising of 39 field crops, 48 horticultural crops and 101 other plant species. However, the most liked ones are pigeon pea, cotton, chick pea, sunflower and tomato. Of the 7-8 generations completed in a year, 3-4 occur on red gram from September to January. It does not undergo diapause in peninsular and central India, but its capability to migrate to long distance jeopardises the protection strategy planned. Time route and causes of migration have not been raveled yet and therefore, forecasting / production efforts and pesticide trademill syndrome need philosophical change.

Natural enemies numbering over 140 are reported in nature. Among the 84 parasitoids, the dependents on egg, egg-larval, larval and larval pupal stage total to 9, 5, 61 and 9. *Trichogramma chilonis*, an egg parasitoid, has not proved to be as potential as in cotton and tomato. *Chrysoperla carnea* is the lone predator that is amenable for augmentative biocontrol among 33 predators, with limited success.

Habitat manipulation primarily to encourage biosuppressants, through intercropping has not been encouraging except for harnessing the benefits from insectivorous birds. Among 16 species of birds that have been recorded to prey on *H. armigera*, black drongo, being the most effective, needs to be exploited through intelligent ecosystem management. Mixing of handful of tall growing local sorghum seeds with seeds of pigeonpea for every hectare is cost effective and requires no skill. Birds clear full grown larvae that pose challenge to all other pest control tools except mechanical collection by shaking plant over cloth. Microbial pesticide HANPV has been quite encouraging as a tool in IPM. Its use for once or twice @ 250 LE/ha with UV protectants and phagostimulants sharpens the efficacy more on chick pea than on pigeon pea. Bt. *B. bassiana* and *Steinernema* sp. have not been very encouraging in pigeon pea.

Pest forecasting or prediction seems to play a vital role in making IPM a successful strategy. Considerable work has been done over two decades on monitoring of pest activity through light and pheromone traps. Combined efforts of UASD and NCIPM, New Delhi has provided all hopes to come close to the development of forecasting system. Rainfall is believed to play pivotal role in upsurging of borer population. Higher premonsoon and monsoon than average rainfall coupled with higher rainfall in November triggers the pest outbreak. Prediction module is being test verified for its accuracy. The outbreak recorded hitherto have agreed with prediction, however, practical adoption of this technology is of less utility since the prediction is possible after recording November rainfall, i.e., after the damage has been caused. Efforts to refine the prediction module before the pest epidemic are in progress.

Undoubtedly insecticides are still the potential tools to combat the pest problem. Nearly of pesticides worth Rs. 100 crores are used on pigeon pea and chick pea for the suppression of borers in Karnataka. There has been greater swing in both qualitative and quantitative use of chemical toxicant. Consequent problem, as in many other cases, has been the loss of sensitivity to pesticides. The borer has developed resistance to endosulfan, monocrotophos, fenvalerate in Gulbarga region. IRM strategies include use of benzooylphenyl urea, methoxyfenozide, nitromethylenes, ovicides, new carbonates, activation of old molecules with plant oils and providing limited and timely slot in IPM schedule. Enhancement of chemical efficacy is influenced by timing, coverage, dosage and appliances used. Through successive investigations, IPM module has been developed and implemented since 1993. The module describes intervention based on monitoring data, use of ovicides, botanical, NPV, erecting bird perches, hand collection and one round of pyrethroid application. IPM of pod borer has been on big way by NGO's KSDA, UAS and pesticide manufacturers.

Key to the success of pod borer management is preparedness to combat the problem in very short period. Therefore, if the early indications of pest appearance and severity is given, developmental agencies, NGO's, farmers, input suppliers can be in readiness to implement IPM over a large area through participatory approach of all concerned.

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PROBLEMS AND PERSPECTIVES OF IPM STRATEGY IN COTTON ECOSYSTEM

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Cotton the 'White gold' is India's principal commercial crop with 9.0 million hectare and ranks first in the world in area and fourth in production with 11.6 bales. The cotton production has remained stagnant over the years and the productivity is also low. One of the reasons for the low productivity is the losses due to pests. More than half the quantity of the pesticides used in the country goes to cotton. Consequent to sole reliance and continued use of pesticides not only control measures have lost their efficacy but also are becoming economically unviable. In India, the pests and diseases cause more than 50% damage to cotton compared to 24.5% world over. There are more than 200 species of insect and mite pests and pathogens affecting cotton of which 30 are most important (Sundaramurthy and Chitra, 1992).

About 54% and 17% of total pesticides are consumed on cotton and rice crops alone though the cropped area under these crops is 5 and 24%, respectively. Andhra Pradesh, Karnataka and Gujarat account for 65% of the total pesticide consumption. Cotton receives nearly 80% of the pyrethroids consumed in the country (Puri *et al.*, 1998). A country wide monitoring programme carried out in six major cotton growing regions from 1992-98, has clearly indicated that pyrethroid resistance is widespread. Resistance to organophosphates and endosulfan was however, medium to low (Russell, 1999).

A carefully designed IPM package involving eco-friendly tools with minimum toxicant usage and verification of this under diversified field condition is the need of the day to tailor the pesticide use on cotton.

Studies were conducted at Regional Research Station, Raichur, on Irrigated cotton for the past ten years and based on the results an IPM module has been suggested which is presently appropriate to manage cotton pests of TBP irrigated area. Regular demonstration of this technique in large areas and training the cotton farmers is the immediate need to convince the farmers about the IPM technology. The cotton IPM module includes various strategies such as modifying the sowing time, use of biorationals, seed treatment to application of appropriate insecticide for the pest and proper application technology (Patil and Bheemanna, 1998).

Major constraints at field level

The major limitation at the field level in the use of bio-agents is the lack of trained manpower. In the case of natural enemies, delay in transshipment which overruns the stage of the pest, short life span, temporal efficacy and lack of knowledge on their use and mass multiplication are the major problems faced by the farmers. Many farmers are of the opinion that natural enemies do not totally suppress the pest populations and low populations are enough to

cause losses. Similarly, use of bio-pesticides is also restricted due to moderate toxicity, slow action, specificity and photo instability. The bioagents are often expensive. The farmers lack knowledge about these. They are not aware of the ecological soundness, proper usage and the source of availability and suppliers of bio-agents and biopesticides.

Botanicals, particularly neem, though readily available has not found favour with farmers. The necessity for repeated application, low toxicity and persistence, cumbersome procedure of collection and extraction coupled with low yields have discouraged the farmers to use them widely. Thus IPM adoption is influenced by cost versus efficacy of products, need for sophisticated information for decision making, ability to integrate new products and techniques into existing farm management practices and managerial skills. Apart from these, the other constraints for wider adoption of IPM include the institutional, informational, sociological and ecological constraints (Patil, 1999).

By overcoming the above constraints and along with regular education of farmers through NGO's, KVK's, extension agencies, research and development units of pesticide companies and demonstration of integrated crop management which also includes Integrated Pest Management, the production and productivity can be considerably increased in India.

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ROLE OF PRIVATE SECTOR IN PROMOTING ENVIRONMENT FRIENDLY PLANT PROTECTION TECHNOLOGY

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Integrated Pest Management (IPM) is basically a planned integration of a range of techniques to minimize the harmful effects of pesticides on the environment by doing away with prophylactic, broad spectrum pesticide use and encouraging build up of populations of natural enemies. The primary aim of IPM is to target the key pest using non chemical methods, mainly biological, so as to encourage build up of natural enemies, which in turn would prevent increase in populations of secondary pests.

In biological control natural enemy populations are strengthened by inundative releases of laboratory reared organisms. The rationale of this approach is to rapidly tilt the ratio of pest to parasitoid/ predator in favour of the latter, thus preventing serious crop damage. In other words, efforts are made to outnumber the pest population to bring about its immediate control without any expectations of long term regulation. Thus, repeated releases every season or some times several releases even during a single season might be necessary. Therefore, mass production of natural enemies becomes an essential pre-requisite for such programmes.

Development of technology

Research efforts have been underway in different parts of the country under the All India Coordinated Research Project on Biological Control of Crop Pests and Weeds to identify environment friendly pest control practices (Singh, 1990). The natural enemies that are now available in India for biological control of various insect crop pests have been listed by Manjunath (1992). These include *Trichogramma chilonis* Ishii, *T. japonicum* Ashmead (Hymenoptera: Trichogrammatidae) for the control of sugarcane borers; *Goniozus nephantidis* (Mues.) (Hymenoptera: Bethyilidae) and *Bracon brevicornis* (Wesm.) (Hymenoptera: Braconidae) for the control of the coconut black headed caterpillar *Opisina arenosella* Walker (Lepidoptera: Xyloryctidae); *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) against various species of melaybugs.

Periodical releases, of the egg-parasitoids *Trichogramma* spp. and the predacious green lacewing *Chrysoperla carnea* Steph. (Neuroptera: Chrysopidae), have been found to result in substantial control of *Helicoverpa armigera* (Hubn.) (Lepidoptera: Noctuidae) infesting cotton and other crops. These, along with Nuclear Polyhedrosis Virus (NPV) and sex pheromone traps, have been recommended as an IPM package against this notorious pest. Similarly, sex pheromone traps and NPV are used against the tobacco caterpillar *Spodoptera litura* F. (Lepidoptera: Noctuidae).

Phytophagous mites are now considered serious pests of many agricultural and horticultural crops in India, including ornamentals grown under protected cultivation (Channa Basavanna, 1999). Although the efficacy of artificially released predatory mites in controlling tetranychid mites on roses grown under polyhouse conditions was demonstrated recently (Mallik *et al.*, 1998), Indian farmers have no access to such products.

Need for setting up commercial biocontrol laboratories in India

The availability of an effective pest management technique alone is no guarantee that it will be adopted and prove effective in the field. It is generally acknowledged that the problem of transfer of technology represents the principal bottleneck, limiting progress of IPM. The success of augmentation programmes mainly depends on the proper selection of natural enemies and their efficient mass production, storage, transport and proper releases.

ICAR Institutes and Agricultural Universities, which have been instrumental in the development and validation of IPM technology cannot be expected to take on the additional responsibility of supplying IPM inputs to farmers all over the country. Considering the magnitude of the task in terms of production figures to be achieved and area to be covered, this does not appear feasible. Private sector can contribute a great deal in translating biological control from precepts to practice by setting up commercial biological control laboratories. However, it is essential that commercial laboratories have the capability to absorb technology and maintain the quality of biocontrol agents supplied. Laboratory scale methods developed by research institutes can be transformed to commercially viable mass rearing methods by appointing qualified scientists and experienced technicians.

The opinion has been voiced by leading scientists that associations of farmers can be entrusted the task of multiplying natural enemies to meet their own demands. Mass production of parasitoids, predators and pathogens is a highly technical job beset with numerous problems. It needs years of experience and knowledge to tackle these problems as and when they arise in order to ensure a continuous production of various colonies. The primary requirement is to ensure the production of adequate numbers of superior quality biocontrol organisms. And to ensure quality it is necessary to have standardised facilities and proper equipments, which are beyond the reach of farmers, ill equipped to absorb such technology. In several countries there are specialised biocontrol laboratories undertaking this responsibility.

Government of India has reoriented its policy on plant protection by adopting IPM as its cardinal principal and main plank of plant protection strategy in the overall crop protection programme (Rajak, 1992). A number of steps have also been taken to draw up guidelines to regulate the quality of biocontrol agents and biopesticides. Availability of standardized products of assured quality will create further demand for such products. Moreover, the Indian farmer is beginning to realize the importance of non-chemical means of pest control, after the recent failures of crops in many states due to development of resistance by pests. However, natural enemies of superior quality are not easily available to the farmers even if they are willing to pay for these. Unless this problem is solved and biological control agents are made as readily available as chemical pesticides, biological control is likely to be treated only as a matter of academic interest.

Taking the above factors into consideration the Project Coordinator, All India Coordinated Research Project on Biological Control of Crop Pests and Weeds called upon the private industry to come forward to set up commercial insectaries (Nagarkatti, 1980). In deference to the above invitation and in order to encourage the use of environment friendly pest control practices Pest Control (India) Limited established Bio-Control Research Laboratories (BCRL) at Bangalore in 1981. In recognition of its unique contribution PCI was given the National Award for Excellence in R&D Efforts in Industry in the Agro Industry Category for the year 1993, by the Department of Scientific and Industrial Research (DSIR), Government of India. BCRL is currently in the process of setting up a state of the art laboratory facility to make available superior quality biocontrol agents.

Constraints faced by commercial biocontrol laboratories

More than 50 biological control laboratories are now in operation in different parts of the country. Commercial biocontrol laboratories face a number of constraints in taking bio-intensive IPM technology to the farmers, among which specificity and low shelf-life of biocontrol agents and non-availability of IPM components to tackle all major pests are the most important. The absence of accurate prediction models on pest outbreaks is a further impediment, in the determination of production targets. Farmers who are attuned to pesticide application find it difficult to switch over to the use of biocontrol agents, mainly due to differences in application methodology, which in turn are not amenable for large-scale utilization.

Majority of Indian farmers have no access to innovative technologies, due to lack of awareness and non-availability of such products with their input suppliers. Moreover, IPM, being a supervised method of pest control, requires trained extension staff to guide the farmers, till they understand the intricacies of need-based application of various components. In this connection BCRL has taken steps to post field assistants in different parts of the country to carry out demonstrations in farmers' field to create awareness and demand for environment-friendly plant protection technology.

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PEST MANAGEMENT CHALLENGES IN COMMERCIAL PRODUCTION OF FRUITS

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The importance India is giving to horticulture production is clearly reflected in the planned budgets. From a modest allocation of Rs. 34.78 million in the fourth plan to Rs. 319.56 million in the seventh plan, resource allocation was hiked to 1102 million in the eighth plan. In the beginning of the nineties, the total horticultural produce was worth only Rs. 452.12 crores, but by 2000 it leaped by nearly three times, matched by a 22% increase in area during the same period. Consequently there has been a paradigm shift in the technological and commercial approach to IPM of insect pests of all horticultural crops, especially fruits. There are two major reasons for this: i) More commercial entrepreneurs entering into fruit production; ii) Increase in quality consciousness in fresh fruit exporters especially in terms of residue-free fruits.

The strategies become clear by the following examples. In the case of mango hopper, *Ideoscopus* spp. the crucial sprays should be timed at pre- and post-blooms. Use of organophosphate compounds is common. However, with the phasing out of the insecticides like monocrotophos, dimethoate, phosphomidon, etc. on the anvil, attempts to introduce newer molecules have been going on at Indian Institute of Horticultural Research (IIHR), Bangalore. Imidacloprid (0.05%) and Lambda cyhalothrin (0.0025%) have proved to be effective with no consequent side effect on pollinators. However, for the more organically conscious farmers two sprays of azadirachtin at a week's interval works as well but with a slower elimination of hoppers. The challenge here is to develop suitable microbial control, say for example, by the use of *Vericillium* which has been found pathogenic to hoppers.

However, the greatest challenge in mango is the management of stone weevil, *Sternonchetus mangiferae* Fab. and fruit fly, *Bactrocera dorsalis* Hendel as they are hindrances to export of fresh fruits to USA, Australia, New Zealand, Japan, etc. In the case of stone weevil IIHR has standardised the following IPM: sanitation (removal of fallen fruits in last season) plus ploughing in October and March plus two sprays of fenthion 0.05% at marble, and lemon size of fruits, both on canopy and trunk. This has worked well in farmers' fields in Andhra Pradesh.

In the case of fruit fly, pre- and post-harvest IPM has been standardized at IIHR (intercultural ploughing in March plus weekly removal of fallen fruits from 45 days prior to harvest plus methyl eugenol trapping plus two to three sprays of decamethrin 0.0028%

(depending on severity) followed by post harvest hot water treatment at $48 \pm 1^\circ \text{C}$ for one hour. The challenge here is to scale –up hot water plants at nodal commercial points like one that has been installed at Vijayawada (Andhra Pradesh).

In grapes, the thrips (*Rhipiphorothrips cruentatus* Hood) and mealybug *Maconellicoccus hirsutus* Green are of major concerns as they directly affect the fruits. Here, the challenge is to prevent pest build up from fore pruning so that insecticidal sprays towards harvest can be totally avoided. At IIHR, a swab mixture comprising insecticides, fungicides, neem oil with sticker applied on trunk following pruning after removal of loose bark, plus raking of soil in the basin considerably reduced the attack of these pests. From a month prior to harvest use of predators (*Cryptolaemus montrouzieri* Mulsant) can be advocated with avoidance of insecticides. Further, this augments the parasitoid, *Anagyrus dactylopi*. However, the challenge is to make use of sufficient predators available between January to March to control mealybugs, while thrips are not a problem at this stage. The swab application also prevents shot-hole borer attack and reduces the insecticidal load on the crop. The exporters of Thompson seedless are already practising swabbing, but availability of predators is a major limitation.

In pomegranate, the fruit piercing moth, *Otheris* spp. has been a major problem. As fruit sucking moths are generally active between October and December, avoiding *mrig bahar* flowering (June to July) will help in avoiding fruits during winter. However, some farmers bring out fruits during this season by netting the entire orchard, as prices are high during this time. This should be taken as a challenge by more pomegranate growers. Further, the bio-agent *Euplectrus maternus* Bhatnagar (Eulophidae: Hymenoptera) is to be integrated. Work on this has been initiated at UAS, Bangalore.

The above illustrations are only pointers of how IPM strategies could shape up. The author has found that the IPM strategies cannot be uniformly applied in different areas of the country. For example, raking the basins in vineyards of Maharashtra is not easily feasible because of black soil and drip irrigation. Here, an additional spray after fruit set is warranted for thrips control.

Another challenge that is emerging before fruit entomologists is the introduced pests. Already the spiralling Whitefly (*Aleurodicus dispersus* Russell) has established and its control is difficult. In a table fruit like guava it is not desirable. There is a report from Tamil Nadu that the adults of the whitefly can be trapped using emergency lamps coated with non-drying glute. But the central issue is to strengthen quarantining to prevent such introductions.

While one desires increase in productivity and acreage, the reverse also may occur. One typical example is the citrus decline in Coorg mainly due to viral diseases. The challenge here is a multidisciplinary approach to vector and virus management involving entomologists, the main challenge will be how to prevent vector alighting on a tree. In this context, mention should be made of papaya ring spot virus transmitted mainly by alate forms of *Aphis gossypii* Glover and *Myzus persicae* (Sulzer) and several

other aphids. Protecting the nursery and early phase of the crops is the challenge before entomologists.

Thus, the paradigm shift in IPM crops will to tailor to quality and residue-free fruits for metro markets and exports. At the same time, cost effective sustainable organic IPM should also merit consideration. Thus IPM in fruits, needs to be not only need-based but also producer – based. Next, with globalization of horticulture, one has to be wary of introduced pests.

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PEST MANAGEMENT CHALLENGES IN COMMERCIAL PRODUCTION OF VEGETABLES

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The last couple of decades have seen phenomenal increase in vegetable production in country. In fact, India ranks second in vegetable production next only to main land China. Increased area under vegetable production especially around large metropolis, introduction of hybrids, varieties, intensive fertigation and plant protection, offseason cultivation, better processing and post harvest technology, organised terminals for domestic and export market, corporate support etc., are some of factors that have contributed to increased vegetable production.

This transition in vegetable cultivation from subsistence to commercial production has not been without fitness cost. Predominantly, insecticide resistance/control failures, resurgence of whitefly, red spider mites and aphids, increased incidence of insect pests, insect transmitted plant pathogens, accidental introduction of new insect pest, vectors and insect transmitted plant pathogens, extensive destruction of indigenous parasitoids and predators are some of the aberrations. Unless scientifically handled some of these aberrations could trigger a cascade effect leading to severe bottlenecks. In a country like ours that is predominantly agro-based and oriented, this could be disastrous. With small land holding, need to maximise economic returns more than the benefit / cost ratio and production by the masses being more relevant than mass production, IPM solutions may have to be evolved more from within than outside to address our problems.

Major pests

The following pests may be considered as major pests on vegetables;

1. Brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee
2. Serpentine leafminer, *Liriomyza trifolii* (Burgess)
3. Whitefly, *Bemesia tabaci* (Gennadius)
4. Gram cater pillar, *Helicoverpa armigera* (Hübner)
5. Diamondback moth, *Plutella xylostella* (Linnaeus)
6. Cutworm, *Spodoptera exigua/ litura* (Hubner)
7. Chilli thrips, *Scirtothrips dorsalis* (Hood)
8. Fruitfly, *Bactrocera cucurbitae* (Coquillet)

The basic reality is that pesticides are here to stay and in future shall form an essential and integral part of crop protection. Paradoxically, with just 3 % of the area, vegetable consumed nearly 17% of the pesticides. Tomato, cabbage, cauliflower, chilli and brinjal are some of the crops that consume a major portion of pesticides.

Insecticide Resistance

Without exception, these insects listed above have developed resistance to a number of insecticides. Ecologically the insect that develops resistance to insecticide(s) has selective advantage in exploiting host plants to its advantage. Further, in such a scenario there is every possibility of keeping its natural enemies at bay. Many of the above pests invest more on environmental (pesticides) resistance than biotic potential and this has ensured their survival and multiplication in a pesticide environment. For the time being, there is an urgent need to concentrate more on Insecticide Resistant Management (IRM). So far, in the Indian context there has been very little work on IRM of insects affecting horticultural crops. IRM is the icing on IPM. In future IRM will become more critical for IPM to succeed.

Yield, Quality and Pesticide Residue

One of the main challenges in the future shall be to increase quality parameters of the produce that is residue free. Environmental standards will become more stringent and crop protection shall no more be viewed in isolation of a state or a country. Pesticide pollution, chronic toxicity, pesticides in food chain, bio-magnification shall become the buzzwords presenting a challenge for export. Though, vegetable production is a high input enterprise, quality parameters and pesticides residue shall be stringent. Paradoxically at the other end, organic farming or pesticide-free vegetable production shall carve a niche for itself in future.

IPM in Protected Cultivation

In the recent past, lot of importance is given to protected cultivation of ornamental and vegetables. Protected cultivation is relevant

- In raising healthy, virus-free nursery
- To raising economically important vegetables during off-season
- Towards seed production of commercially important hybrids

How far protected cultivation of vegetables is feasible and shall be in vogue is dependent on market forces. However, IPM of vegetable pests in such a scenario shall be focussed on thrips, mites, aphids, leafminers and whiteflies than any other pests. The management of these pests has to do more with the design of the glasshouse itself.

Vector Management

Perhaps the greatest challenge to vegetable production is from insect transmitted plant pathogens viz. viruses, mycoplasma, bacteria etc. normally the ETL for vectors is so low, that vector management is of little relevance. Host-plant resistance to viruses is

the best ecologically and economically viable alternative. However, it takes time and success depends on location of source of resistance and incorporation of resistance to get commercially acceptable varieties / hybrids. Use of insecticides for the control of vectors is more practical if the mode of transmission is persistent but may counter if the transmission is non- persistent.

Thus, any Integrated Pest Management (IPM) has become more of Intelligent Pest Management or Intelligent Pesticide Management. Without doubt, this involves avoiding indiscriminate use of insecticides. However, this has to be done on a scientific basis. Towards this, the following concerns have to be addressed in near future.

In short, IPM for commercial production of vegetable should address the following points;

- a) Is IPM possible in all situations? Specifically, are insecticides the only solution in many situations?
- b) Is it possible to reduce the insecticide load beyond a point without sacrificing yield and quality in commercial vegetable production?
- c) What should be the future thrust on insecticide mixture?
- d) What are the missing links in the transfer of IPM technology?
- e) How the knowledge to IT is harnessed towards IPM in horticulture?
- f) Can biotechnology with transgenic *Bt* etc. provide solution to pest control?
- g) What will be the environmental and ecological implications of GM plants?
- h) How will be the development of resistance in GM plants?
- i) How GM plants can influence/ affect biological control?

Transgenic Plants

Use of GM plants and advanced molecular methods in future IPM is a reality. However, at a national level technical and policy matter have to be sorted out prior to implementation of this technology.

In addition to these aspects two other aspects come to focus that shall remain widely believed that in future genetically modified (GM) crops should play a major role in future plant protection. Are GM plant parts and products edible? Will this lead to new set of pest management problems? How to assesses the environmental impact of these GM crops? What will be the role insecticides and bio-control agents in this changing scenario? These and a number of environmental, social and ethical issues are to be addressed at the policy level. Largely, this will be facilitated by the IT revolution sweeping the entire world. Thus, in future IPM in vegetable crops shall have to address more of environmental, ethical and social issues that are not easy but challenging all the same.

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INSECT SYSTEMATICS – PRESENT STATUS AND FUTURE DIRECTIONS FOR INSECT SYSTEMATICS IN INDIA

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The study of the great diversity of organisms that abound our planet and their relationships to each other forms the subject of systematics. Though systematics of plants and higher animals has advanced tremendously, the same is not true of insects because of the multitude of insect species (close to one million) that constitute almost 80 per cent of the described animal taxa. Systematics of any group of organisms passes through three stages of development. **Alpha taxonomy**, the first stage where new species are described, named and are arranged in comprehensive genera. **Beta taxonomy**, the second stage, involves synthesis of these species into higher categories based on their relationships so as arrive at a natural classification and derivation of principles of predictive value. The third stage is the **gamma taxonomy** that deals with studies on the intra-specific variation. The systematics of any group of organisms may also develop along these stages concurrently.

To bring in objectivity in classification several principles have been developed in the past. These can be grouped into three leading schools; the evolutionary school, the cladistics school and the phenetic or numerical school (Mayr 1969). Willi Hennig (1950) in his treatise entitled "Grundzüge einer Theorie der Phylogenetischen Systematik" enunciated principles to classify organisms in a rational way. In this system higher categories are recognised based on detailed character analysis and the classification thus constructed could be tested with geological and parasitological evidences. Hennig's principles are now being widely followed by many plant and animal systematists.

Advances in molecular biology have provided new tools to re-evaluate the schemes of classifications that are followed based on non-molecular data. The conservative gene sequences in ribosomal and mitochondrial RNA are being looked at as candidate areas to explore the relationships among otherwise controversial groupings arrived at based on traditional morphological or behavioural traits.

Among insects, the higher classification at the order level, suborder and family level are being intensively researched using 16s, 18s, 28s rRNA, mitochondrial protein-coding gene ND-1. Familial and suborder classification of the insect orders Orthoptera, Hemiptera, Coleoptera, Diptera, relationships of the enigmatic Strepsiptera with other insect orders etc., are being studied in the leading systematic entomology laboratories of the world. It has to be said with deep regret, that in India the science of insect systematics has failed to keep pace with the advances made worldwide. This is probably so due to several reasons, chief among them could be lack of extensive study material on a world-wide basis, poor funding, apathy of the scientific establishment and a lack of trained personnel well versed in both philosophy and techniques of systematics. The latter however, has clearly stemmed from branding of systematics as 'merely stamp collecting' by agencies and individuals who

have shaped the science policy of the country. Given this situation it is hardly surprising that few young students opt for insect systematics as a career. The state of 'national' insect collections in the country is also not very satisfactory and not readily accessible for the study even by specialists in India.

Most of the insect systematists from India and those working on the Indian fauna from abroad are concentrating only on alpha taxonomy. There is hardly any work dealing with beta taxonomy. The groups of insects that are fairly well known (though it is estimated that we know about 30% of our insect fauna and that the fauna is being destroyed in an alarming manner with destruction of their habitat by the ever increasing human population) are butterflies, mantids, short-horned grasshoppers, psyllids, aphids, whiteflies, fruit flies, some groups of moths, vespid wasps, parasitic Hymenoptera (though there are a few groups which need attention) syrphid flies, Thrips, agromyzid flies, mosquitoes, bed bugs, fleas, sucking and chewing lice, tiger beetles, carabid beetles, phytophagous chafer beetles, etc.

The Department of Entomology of this university has pioneered the study on several groups of insects and mites. Systematics has been fostered during the periods of Leslie C. Coleman, T. V. Subramanian, M. Puttarudrah, G. P. ChannaBasavanna and G.K. Veeresh and continues even today. Apart from the taxonomic studies on phytophagous mites, studies on termites, carabid beetles, tiger beetles, root grubs, dung beetles, ladybird beetles, flea beetles, fruit flies, ants, grasshoppers, thrips, earwigs, hover flies, leafhoppers, reduviid bugs hairy caterpillar moths etc have been carried out in the past and continue to be vigorously pursued. International collaborations especially in the studies on root grubs, leafhoppers, fruit flies and tiger beetles have been established.

Future needs and prospects

With the destruction of natural ecosystem at an alarming rate in India, it is time that we open our eyes at least to catalogue the diversity that we keep talking about. Without this it would be almost impossible to develop a strategy to conserve the rich biological diversity of our country.

Both governmental and non-governmental organisations may develop creative schemes to infuse young blood for nature study not only to create awareness among the younger generation but also to induce them to take up nature study as a career option. Attractively illustrated but affordably priced handbooks of different groups of insects need to be brought out so children begin to take interest in insects from a very early age. This would also encourage amateur entomologists who can also make significant contributions to insect systematics as has happened elsewhere in the world. School and college authorities should not hesitate to overhaul the biology syllabi at all levels and include mandatory nature study projects, which are now almost entirely lacking or confined only to the four walls of the schools or colleges.

Institutes and individuals who are seriously pursuing insect systematics should come forward to train willing youngsters and ensure that a new generation of trained systematists always ready to take over the mantle from their seniors. Scientific societies that are publishing various journals should not flinch from reporting systematic papers of merit and journals are already doing so should improve the

quality of illustrations that are printed and raise the standards of refereeing. Further a society of systematic entomologists should be floated to foster this dwindling science both in manpower as well as funding. When it comes to funding there are two aspects that need to be addressed. The first concerns increased allocation of both importance and finances to fund projects of well established systematists. The second suggestion is to launch a national programme along the lines of young scientists projects which could be termed, 'young associate in systematics' to support merited individuals, for periods ranging from two to five years, after completion of Ph.D.

There is a bright future for systematic studies as greater emphasis is being laid on biodiversity and conservation of the same. There are not many specialists available now to accurately identify many groups of even common insects either in the country or abroad. Redefining the goals and proper planning to foster this branch of science which is the foundation for all other sciences will not only strengthen systematic studies of the groups, help in developing conservation strategies on a scientific basis but also give new direction to existing and developing sciences in biology.

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PEST MANAGEMENT PROBLEMS IN COCONUT AND ARECANUT

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Coconut and arecanut are two of the major plantation crops of peninsular India. Coconut is primarily a coastal palm. It is now being extensively cultivated in the hilly tracts and plains of the inland. Similarly, arecanut, once a crop of the malnad belt, is today thriving well even in the maidans. Vast stretches of low-lying paddy lands are being converted into arecanut plantations. It has to be noted here that, these two commercially important crops are subjected to highly varied climatic conditions which, in turn, influence the pest complex that occurs on the crop.

The most important factor that one has to thoroughly examine in any pest management would be the climatic conditions prevalent in that area. It not only influences the pest complex but also their dependent factors mainly natural enemies, the most important component in pest management.

The major pest towards which most of the pest management programmes have been devoted are, rhinoceros beetles, black headed caterpillar, red palm weevil and eriophyid mite in coconut; white grubs, mites, scales and mealy bugs and inflorescence caterpillar in arecanut.

Coconut

Management strategies for rhinoceros beetle (*Oryctes rhinoceros*) has revolved around usage of *Baculovirus* and *Mterrhaziu anisoplae* as biocontrol agents, mechanical and chemical exclusion of grubs from the compost pits, mechanical exclusion of adults, adult deterrence from feeding and trapping adults either through pheromones or baits. The major drawback in its successful management includes poor extension education of these technologies to the needy farmers and scarcity/ non availability of biocontrol agents. Research needs to be geared up in understanding reproductive biology and ecology, its population dynamics in relation to the natural enemies in various climatic zones. Research workers need to utilise trapping methods and revise the management protocol and systematic breeding and release programme of other promising natural enemies (e.g. The Reduviid, *Platymeris laevicollis*) should be immediately looked into.

The black headed caterpillar (*Opisina urenosella*) has received, probable the most extensive attention and uniform management treatments. In spite of systematic attempt having a parasite breeding laboratory at all coconut growing areas for timely release of natural enemies, subsidised distribution of appropriate chemicals, proper application technologies available and state department workers taking up management on campaign basis, the pest has not been checked. Immediate work to its spread and hence so forecasting its occurrence is need. An effective mass multiplication technique for this

pest so as to be used in rearing its specific natural enemies is immediately wanted. Also, an effective substitute for monocrotophos (may even be botanicals) has to be urgently brought out.

Rhynchophoru ferrugineus, red palm weevil has largely endemic occurrence. To avoid inflicting wounds to palm, sanitation, trapping using pheromones and food/oviposition baits and chemical control are the major management methods available. However, lack of a suitable method for early detection of the pest is hindering its management. Also use of natural enemies is clearly missing from the schedule. A complete management protocol against this pest is also to be developed and tested. Information regarding its behaviour, population dynamics and basic ecology is still wanting.

The coconut eriophyid mite *Aceria guerreronius* has received the highest attention since a couple of years. Only chemical control using triazophos and monocrotophos provides considerable population reduction. Botanicals, including neem and garlic, are reported to show promise. This newly introduced pest urgently needs investigation on all aspects of its basic biology, spread and interaction with its natural enemies. Coconut lines have to be screened for the resistance to mite (probably lines with compact perianth).

Arecanut

Three species *Leucopholis lepidophora*, *L. coneophora* and *L. burmeisteri* constitute arecanut white grub group. A detailed management schedule is available which is showing positive results. However, usage of natural enemies, *Beauveria bassiana*, *B. brongniarti*, *Heterorhabditis* strain for Western Ghats and to test strains of *Bacillus thuringiensis* specific to Coleoptera and explore the possibility of conserving scoliid parasitoids for natural control.

Scales and mealy bugs from a group that increase in population during summer months. They infest the inflorescence, nuts and even leaves. Their management involves exclusion of ants that associate with the bugs. Sprays of synthetic chemicals and neem oil spray. Through many natural enemies, especially coccinellids are available, systematic multiplication and release programmes is yet to be done.

The species of mites, *Oligonychus indicus*, *O. fijiensis* and *Raoiella indica*, are known to cause serious damage during months of the year. Apart from spraying dicofol there is no other management recommended. *Stethorus keralicus* and phytoseiid predators show much promise. However, there is a need to conduct studies in this regard. The dispersal behaviour and dispersal stage has to be carefully noted so that timely management can be taken up.

The inflorescence caterpillar, *Tirathaba mundella* is known to be serious where ever slug and snails have gnawed the spathe. Its management includes two aspects. Firstly, exclusion of the predisposing factors and secondly, spraying endosulfan to the

affected inflorescence. This pest too has received little attention with respect to its basic biology and ecology. No natural enemies have been explored for the possibility of bringing biological control of the pest.

These are some of the major pests only. However, there is an immediate necessity to recognise those pests that have a potential to be major like a leaf eating caterpillar (*Latoia lepida*, *Macropsectra nararia*) and shot hole borers of coconut, spindle bug on arecanut and such others.

SERICULTURE - PROSPECTS AND PROBLEMS

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Silk in India is as old as civilization. There are historical and scientific evidences to indicate that silk worms had their origin in the Sub-Himalayan regions of India, although it is generally claimed that silk production originated in China. No other fabric can match the silk for its luxury, luster and elegance and so it is called the queen of textiles in its long history. Indian Sericulture has witnessed periods of boon and recession.

In the post independence era, sericulture received prime importance by planners, as means to generate gainful employment opportunities to under employed and unemployed rural poor. It is well known that sericulture is a labour intensive industry involving mulberry cultivation, egg production, silkworm rearing, silk reeling and weaving.

Since mid 1970's, sericulture has rapidly progressed fast in developing countries. Now, China contributes 63 per cent of the total global raw silk production and India adds 16.1 per cent and the rest from other countries. In spite of this, silk occupies only about 0.17 per cent of the total textile fibers in the world. Despite the fact that India occupies second position in the global raw silk production, the production per unit area and the quality of the silk produced are very low compared to those of China and Japan. In addition, the poor socio-economic condition of the sericulturists, vagaries of tropical environment, sub-optimum quality of the leaf, poor rearing conditions and want of suitable races/ hybrids are the prevailing perennial problems of the Industry.

Sericulturist in the past was never sure of his cocoon crops and an element of risk always haunted him. With the advent of new technology of silkworm rearing, this situation has completely changed. The age old silkworm hybrids have been replaced by productive hybrids. In addition, proper management of mulberry garden and new technology of silkworm rearing ensure the sustained crops of bumper yields.

Specific mulberry variety (S₃₆) has been identified for young silkworm rearing. Victory-1 mulberry variety yields 65,000 to 70,000 kg of leaf per hectare / annum under irrigation compared to 35,000 kg of M₅ (Kanva-2), the ruling variety in Karnataka. The silk productivity in early 1970's ranged from 15 to 20 kg per hectare, which increased to 46 kg per hectare by mid 1990's. Further, over the years the renditta has come down from 13 to 8.5 kg under irrigated mulberry system. The CSR hybrids have the yielding potential of 70 kg per 100 DFLs with renditta of six kg and with raw silk grade of 2A – 3A.

To meet the demands of sericulturists, about 31.99 crore cross breed layings per annum are being produced in Government and private grainages. A total of 12,954 tonnes of raw silk was produced, with an annual growth rate production at 23.3 per cent. As far as silk weaving is concerned, the handlooms account for about 65 per cent (1,82,000), the rest being the powerlooms (31,000) in silk fabric production. These looms consumed nearly 85 per cent of the total raw silk for weaving traditional sarees.

Constraints

Mulberry cultivation practices remain more or less unchanged for years, as many of the farmers are incapable of uprooting the existing mulberry variety to replace with the high yielding varieties. Similarly, though the farmers are aware of the inputs, they are not in a position to provide the same due to several limitations. Scarcity of the underground water and unpredictable-rainfall have added to the problem, resulting in substandard mulberry leaf production, ultimately affecting the cocoon production.

The silkworm rearing practices have to witness change in view of new technology. The quality of silkworm egg has not altered much since several years. The efforts to introduce high yielding silkworm breeds have met with little success.

The cocoon processing and reeling technologies have to be transformed. In view of the static condition of the above components, adoption of new technologies has become a matter of debate among the scientists and administrators.

The success and rapid expansion programmes undertaken by the Government agencies, the sustained efforts R & D establishments to upgrade the technology will certainly yield rich dividend. Then it is possible for the Indian Sericulture Industry to shed its image of having distinction of low productivity per unit area as well as production of inferior grade raw silk and change over to high quality final products which can be accepted by the average consumers of international community.

NEW HORIZONS IN BEE POLLINATION

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Majority of the angiosperms have to undergo pollination for their conservation in the ecosystem. Particularly for species with monoecious flowers, cross pollination is a must. Factors such as self incompatibility, non-synchrony in the development of reproductive parts, certain physical and chemical barriers between male and female reproductive parts also contribute to the promotion of cross pollination. Among various agents of pollination, bees including both honey bees and other bees are by far the best ones. Honey bees have been utilised for pollination commercially with the advent of movable hives. There is vast knowledge accumulated on the role of honey bees in pollination of crops (McGregor, 1976; Free, 1933; Roubik, 1995).

However, the utilization of honeybees commercially for pollination of crops has been made since 1960s. That apart, other non-*Apis* pollinators such as leaf cutter bees, alkali bees, bumble bees, carpenter bees and stingless bees have attracted greater attention due to their enormous potentiality to pollinate crops. In the present article only recent developments and possible future areas of commercial pollination have been presented.

Honey bees

Special attention has been given to develop colonies meant for pollination. The colonies with higher proportion of bees collecting pollen of a particular crop have been selectively bred for the purpose. Such colonies are capable of hoarding pollen 13 times more than the others. It took normally 5-6 generations to develop colonies having preference to a particular crop say, alfalfa.

To increase the pollination, bees will have to be stimulated to collect more pollen. This has been made possible through mentioned below;

1. The application of been attractants in the form of bee lures such as, Bee Q, Bee scent and synthetic pheromones such as Nasonova pheromone, brood pheromone, etc.
2. Feeding the bees with sugar syrup to promote pollen collection by 2-5 times, thereby enhancing pollination.
3. Setting up pollen trap or removal of pollen store, which tend to increase pollen collection hence, pollination.
4. Fixing soft nylon bristles at the entrance helps in increasing the transfer of pollen among foragers with respect to number and kind of pollen in turn enhancing cross pollination.
5. Use of pollen dispensers containing manually collected pollen, thus allowing bees to carry pollen while moving out to the crop patch.

6. Utilizing bee collected pollen for pollination through pollen dispensers, which circumvents costly hand or mechanical collection and dispersal.
7. Providing more brood thereby promoting more pollen collection as to feed the additional brood.

Solitary Bees

Leaf cutter bees are potential candidates to be utilised in pollination. It has been possible to develop artificial, wooden tunneled, domiciles for rearing them. E.g., *Megachile rotundata* is mass reared for alfalfa pollination in United States. These bees @ 2000-3000 / ha, would suffice for alfalfa pollination. Short foraging range, higher number of flower visits / minute, oligolectic nature go in its favour.

Alkali bees is yet another yet another group of under exploited, non-Apis, solitary bee species nesting in soil. Artificial domiciles in soil for *Nomia melandari* has been developed and commercially exploited for alfalfa pollination. More than 2000 nests / m² that it builds show the prolific nature of this species. Many more are to be looked into for commercial exploitation.

Osmia spp., *Rhopitoides* sp., *Peponapis* sp. and *Pithitis* sp. also have great potential for commercial exploitation in pollination of various crops. Thoroughness, quick visits, large number of visits per unit time make them deserving candidates to be focused upon.

Carpenter bees also are efficient pollinators exploited to certain extent in pollination of passion fruit. Special hives and multiplication methods have been developed. *Xylecopa* spp. of this group has tendency to pollinate wine species due to trellies orientation, hence, stands better chance in pollination of such crops.

Stingless Bees

Melliponinae constitutes a large number of stingless bees which play immense role in pollination of crops. These are medium sized ones, and are major flower visitors in tropics. Social organisation in these is similar to one in honey bees. Colonies have 100-1000s of workers. Polylecty, floral constancy, perennial nature, possibility of domestication, large food reserve, in-hive pollen transfer and forager recruitment in these species make them able pollinators in many crops. They can be reared in artificial nests. They are harmless to man. They can be handled easily. This is the group of pollinators to be exploited fully.

Bumble Bees

Bumble bees as group, include important commercially exploited pollinator species. They are less social than honey bees. For many species, artificial nest sites have been developed. The multiplication method, preserving the colonies during adverse seasons, transportation of colonies have been developed to some of these species. They

are known for buzz pollination. Their utility in pollination of tomato crop grown in green house is fully exploited.

There is vast potential still to be exploited for the purpose of pollination by understanding the behaviour of honey bees. Also, there are large number of non-*Apis* bees need to be studied species wise and their preference for a particular crop, their biology and nesting behaviour will have to be understood for their use in specific crops. It is quite likely that they have a greater role to play in pollination of certain plant species than that of honey bees.

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AGRICULTURAL ACAROLGY IN INDIA DURING TWENTY FIRST CENTURY- A PROJECTION

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It is appropriate to know the progress achieved so far in our understanding of the mite fauna on plants of this vast country, their biology and other aspects of plant mites, before an attempt is made to project the trends of development or rather offer suggestions for the development of this area of science during the twenty first century.

The year 1868 has a special significance in the development of agricultural acarology in India, because a plant feeding mite was reported on tea during this year (Peal, 1868) and thus marked the beginning of studies on plant mites in this country. This mite on tea which was recognised more than a century ago is an important pest of tea even now, and is a matter of great concern in tea plantations all over the country. Agricultural Acarology showed rather a slow progress during the century following this year, recording only 36 species of plant feeding mites (Ghai, 1964) which also included this mite reported from Karnataka in the First All India Congress of Zoology held in 1959 at Jabalpur (Puttarudriah and ChannaBasavanna, 1962). It is not only in respect of the number of species but also with regard to our knowledge on other aspects such as biology and control of these mites the available information has been limited (Wood-Mason, 1884; Watt and Mann, 1903; Cherian, 1933; Rahman and Sapra, 1940; Janjua, 1942; Lall and Dutta, 1959; Das, 1959; Das, 1959; Das and sengupta, 1958, 1963 etc), being confined to serious pest species.

However, the next 3-4 decades witnessed a remarkable progress in the study of plant mites. A number of workers have contributed to the progress, both in respect of faunistic studies and different aspects of biology and control of plant feeding mites. Among the important ones are ChannaBasavanna (1966), Menon and Ghai (1968a, 1968b, 1971) Gupta and Dhooira (1972), Gupta (1976), Gupta and Gupta (1976, 1977) Nassar and Ghai (1981). In an extensive study of eriophyoid fauna of the country earlier in 1960s (ChannaBasavanna, 1966) 44 new species in addition to new records were reported along with description of the species. Another review of plant feeding mites in India (ChannaBasavanna, 1971) was presented in the Third International Congress of Acarology held in Czechoslovakia, which included 111 species of which 70 species belonged to Eriophyoidea. Almost at the same time and a little later a bibliography of plant feeding mites (ChannaBasavanna and Nageshachandra 1971; ChannaBasavanna *et al.*, 1971), appeared and this included all the titles of papers published upto that time. Another significant contribution by way of catalogue of mites occurring in India was by Prasad (1974). A number of taxonomic contributions have appeared in recent years: Nassar and Ghai (1981), Maninder and Ghai (1978), Mohanasundaram (1980a, 1980b, 1980c, 1981a, 1981b, 1982, 1995) and Chakrabarti and his colleagues (1980-1982). In a recent book dealing with the description of plant mites of the country (Gupta, 1985) and in more recent review (Gupta, 1991) around 600 species of plant mites are included of which 421 are phytophagous.

Studies on the biology of plant feeding mites have been confined mostly to economic species. Most of these studies were confined to elucidation of the life cycle under laboratory conditions, nature of damage, etc. rather than in depth studies on the field biology, population dynamics and the causes for the same which were restricted to only a few species. One of the earliest species to receive attention in this direction was the tea spider mite *Tetranychus bioculatus* (Wood-Mason 1884, Watt and Mann 1903). Another common spider mite pest of sorghum and sugarcane (*Oligonychus indicus* Hirst) received attention from early workers (Cherian, 1933; Rahman and Sapra, 1940) for the study of its biology. Another common spider mite which is polyphagous and a pest of a number of vegetable crops, cotton, jute, etc. (*Tetranychus telarius* Linnaeus) was studied extensively, for its biology and control (Janjua, 1942; Lall and Dutta, 1959; and others). It is obvious that two or three species were involved in these early reports, namely, *T.cinnabarinus* (Boisduval), *T.ludeni* Zacher and *T.neocaledonicus* Andre. Rahman and Sapra (1946) and Khol and Patel (1956) investigated the biology of *T. equatorius*. The biology of another species of spider mite *Oligonychus oryzae* (Hirst) which becomes an important pest of rice especially during wet seasons having bright sunny days with intermittent rains has been studied fairly in good detail (Misra and Israel, 1968). The brown wheat

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mite *Petrobia latens* is another important pest in the northern wheat growing areas of the country, infesting wheat and barley. It is interesting to note that this spider mite lays two types of eggs, winter eggs and summer eggs, the latter hatching only during next winter (Khan *et al.*, 1969). Another spider mite *Eutetranychus orientalis* which is highly polyphagous and at times becomes quite serious pest of citrus was extensively investigated for various aspects of its biology (Banu and ChannaBasavanna, 1972; Dhooria, 1981; 1982, 1983, 1993; Dhoria and Butani, 1981, 1982a, 1982b). The population of this mite is mostly found on the upper surface of leaves while many other spider mites mostly inhabit lower surface of leaves.

The important pest species of tea namely *Oligonychus coffeae* (Nietner), *Acaphylla theae* (Watt) and *Calacarus carinatus* (Green) have been studied fairly in great detail for their biology under Assam conditions (Das, 1959; Das and Sengupta, 1958, 1963). The common vegetable mite which also infests other crops (*Tetranychus ludeni*) has been studied for various aspects of biology in later years also (Puttaswamy and ChannaBasavanna, 1979a, 1979b, 1980a, 1980b, 1981a, 1981b).

Regarding management of mite pests, it has been mostly through use of pesticides. In the beginning when synthetic organic compounds were not available, sulfur was the ruling acaricide. In spite of the availability of synthetic compounds sulfur still continues as an acaricide on account of its efficacy against many groups of mites as well as the relatively low cost. Basu and Pramanick (1969) stated that sulfur was the cheapest (Rs.1.06/spray) while some other equally effective chemicals were about 20 times more expensive (Chlorobezilate, Rs.21.60/spray).

Chlorinated hydrocarbon insecticides like DDT are known to generally increase mite populations, while several organophosphorus compounds have been successfully used as acaricides. Organophosphorus insecticides like phosphamidon, dimethoate, phosalone, etc., are equally effective as acaricides like dicofol and binapacryl (Tripathi and Sriram, 1970). While there were a number of efforts to screen different chemicals and utilize them in the control of mite pests of crops, there were hardly any studies to find out safer acaricides to natural enemies of mite pests in India or there were sustained investigations to identify promising predators and utilize them in the management of mite pests of crops (AnanthaKrishnan, 1963; Bindra *et al.*, 1970; Awate *et al.*, 1981; Dhooria and Butani, 1982; Sannaveerappanavar and ChannaBasavanna 1986; Naidu and ChannaBasavanna 1989; Dhehirabeevi and Natarajan, 1992).

Some studies have been initiated, however to investigate the biology of the common predatory mite *Amblyseius tetranychivorus* (Gupta) and to find out selectivity of acaricides with a view to determine acaricides safer to the phytoseiid predators. Puttaswamy and ChannaBasavanna (1981b, 1983), Nangia and ChannaBasavanna (1982, 1983a, 1983b, 1983c, 1984, 1995) and Jagadish and ChannaBasavanna (1983a, 1983b) have contributed to our knowledge of the biology of *A. tetranychivorus*, on the effect of some of the commonly used acaricides in an effort to utilize the predatory mite in the integrated control of some of the spider mite pests of crops. Seasonal variations of populations of *Brevipalpus phoenicis* and *Amblyseius alstoniae* on guava were studied recently (Kumari and Sadana, 1995). Even mathematical models for the interaction between *T. ludeni* and its phytoseiid predators were prepared (Mallik *et al.*, 1989).

Several factors contribute for the development of a branch of science in a country. The rapid progress witnessed during the last 3-4 decades in India as compared to that during the previous one hundred years may be attributed to certain developments in the country. The gradual increase in the awareness of importance of plant mites in agricultural systems and its realisation among the concerned scientists and farmers and the creation of needed infrastructure facilities through funding even from external sources are the most important factors that have contributed to the development. The infrastructure facilities may be in the form of setting up suitable laboratories, training the required manpower and providing suitable atmosphere for work.

The Acarological Society of India (ASI) which was established in 1974 with the main objective of fostering development of acarology in the country through organising symposia, seminars etc. and training programmes, publishing periodicals, bulletins and books etc. in acarology and encouraging young scientists by way of instituting awards. Among the developing countries, India is the only country to start an exclusive society for acarology. Currently the Society is publishing two

scientific periodicals, Journal of Acarology (previously Indian Journal of Acarology) and Acarology Newsletter. The ASI has 62 life members. Publication of our own periodicals devoted exclusively for acarology is a decided advantage to Indian acarologists to get their research findings published readily and without paying any page charges as required by some of the foreign journals.

The ASI in collaboration with other agencies has organised five national symposia at different places in the country and this is the sixth in the series. It need not be mentioned that such arrangements to meet fellow acarologists periodically provide wonderful opportunities to exchange ideas and discuss several matters concerning acarological problems. Recognizing the active and useful role played by the ASI, the International Executive Committee agreed to hold the VII International Congress of Acarology at Bangalore in 1986. It may be noted that this Congress was held for the first time in the east and in India. The Society organised this Congress with great success. Two training programmes in Acarology at the national level in addition to the programmes in different groups of mites and various aspects for smaller groups of specific requirement have been organised by the Society. These national level training programmes provided good opportunity to young research workers in this country for getting themselves trained in various techniques as well as basic theoretical aspects of acarology. In addition, these programmes helped inducting at least some of them to research in acarology. Individual workers were also given training on request.

It is heartening to note that during this period, some of the Universities, mainly Agricultural Universities at Ludhiana, Bangalore, Coimbatore, Calicut and a few other centres have developed post-graduate teaching and research programmes in acarology. Such programmes not only help fostering acarology in a general way but also train the much needed man power in acarology research in the this country.

Realizing the importance of acarology, the Indian Council of Agricultural Research besides supporting a number of ad-hoc research projects submitted by individual scientists working in various Universities and organisations, sponsored the All India Multilocational Research Project on Agricultural Acarology which was operated in eight centres spread over the country, which was later converted into a full fledged Co-ordinated Research Project on Agricultural Acarology being operated now in eight centres. This is a unique opportunity provided to acarologists in this country to contribute to our knowledge of plant mites. This comprehensive project being operated over the last 12 years has accumulated a vast knowledge on plant mite fauna of the country besides the biology of the important mite pests of crops and developing integrated management of mite pests.

Having reviewed development of agricultural acarology so far in a nutshell in this country, it is worthwhile to turn our attention to what acarology is going to be during the upcoming 21st Century. It would be more realistic and useful to offer some suggestions towards developing agricultural acarology rather than conjecturing what is going to happen.

Though considerable progress has been achieved in the recent past in certain areas of acarology, there are wide gaps in our knowledge of various groups of mites as occurring in different parts of this vast country as also other areas which are needed for a rational approach towards the management of mite pests of crops. Keeping this in view the following suggestions are offered.

Biodiversity

Biodiversity is natural and is considered by all right thinking persons to be essential for balance of life in nature and thus is the duty of every citizen to conserve the same. When conservation of this diversity is considered essential to know exactly what to conserve and that means a knowledge of the organisms that constitute this diversity. In a vast country like ours it is a stupendous task to undertake a survey for the organisms and yet it has to be done. There are vast areas in this country in which such a knowledge is not available and there are other areas which are poorly explored. It therefore becomes imperative to build up information for which regionwise exploration has to be planned and executed. Without a thorough knowledge of what is expected to be conserved our idea of conservation remains a glib talk without achieving desired goal. The success of this project depends very much on a strong taxonomic base through which correct identities of organisms are established.

It is a team work of a large number of committed workers operating in different parts of the country. The Universities that have already developed post-graduate programmes in acarology and other such institutions may co-operate in developing taxonomic centres. It is not only mere species composition that is needed to be understood but also the relative abundance or scarcity of different species in a region. This inventory is essential and is a prerequisite for any conservation programme.

Ethology

Studies on the behavior of mites are essential in order to have a thorough insight into the various aspects of life of a mite. Certain aspects of behaviour, such as reproductive behaviour, dispersal behaviour, host searching behaviour and such others, understanding of which leads to a rational and effective approach towards management of pest species need to be investigated.

Natural selection favours such attributes which account for the success of the individual. Individuals which exhibit such behaviour which makes successful foragers being effective in their search for food, which helps them to escape from enemies when encountered and so on are favoured. An intensive study of these various aspects of behavior helps us to understand and perhaps certain aspects may lead to devising ways to manage their populations. Reproductive behavior, especially parthenogenesis and vivipary confer on the species certain benefits in building up population which otherwise would take more time to search for mate or expose eggs for predation. In sexual reproduction the role of sex pheromones especially in phytoseiid mites is important and needs to be investigated.

Mites because of lack of wings and of limited mobility thus find it hard to disperse quickly and occupy the required habitat. Dispersal, therefore, is a crucial event in the life of a mite and largely determines survival and build up of population. Still, certain species have developed methods such as ballooning which consists of congregation of mites usually at the terminal points of plants for being wafted by strong breeze and thus land on a new plant, or phoretic ride on an insect and thus taken to new plants/places. Such behaviour, though full of risks for individuals, offers the mite quicker means of transport. However, the major plant feeding groups and predatory mites, are not known to exhibit phoretic behavior, though "ballooning" and dispersal through air current are known to be the methods of dispersal in these groups, the success or failure of such dispersal behavior depends to a great extent on whether the mite is inhabiting a pure stand of a single crop or whether it is in the midst of different species of host and non host plants. Dispersal behavior is poorly understood in many pest and predatory mites.

Yield loss due to mites

It is the usual practice for economic entomologists/acarologists to base their judgment on the severity or otherwise of mite feeding on a crop on the bases of numbers of mites present or the symptoms caused on the crop. Though this procedure may provide some idea of the crop loss caused due to mite infestation, it does not lead to estimating precisely the quantum of loss. The quantum of loss due to a mite is the one factor that appeals to an administrator or an extension worker and helps him to take decision in favor of its further investigation leading to its management. Though some limited number of studies are initiated to determine the methods of determine the crop loss due to some important mite pests, there is a great need for studies to be undertaken in respect of all important mite pests in the country.

Management of mite pests

The usual method to tackle mite pests is through use of chemicals which are toxic to the concerned mite pests. Unilateral dependence on this method leads to several undesirable effects such as development of resistance to pesticides by the pests, decimation of predators, emergence of secondary pests, etc. It is in this context that safer and environment friendly methods are considered for total or partial replacement of the chemical method. Some of these which have received very little or no attention in this country are suggested.

i. Host plant resistance

As is well known that the greatest advantage of this approach is its compatibility with other methods. Even partial resistance can be exploited in the management of mite pests. Identification of resistant cultivars and either adopting them directly for cultivation or using them in the breeding programmes should be a major approach in the integrated control systems. Thus collaborative research between plant breeders and acarologists is crucial for management of mite pests. At present there are hardly any projects in resistance breeding in this country.

ii. Biological control

Conservation of natural enemies: Utilization's of natural enemies of mite pests is another environment friendly approach in the management of injurious mites. Among the natural enemies are principally the predatory mites and insects and secondarily the disease causing agents like fungi and viruses. Our aim in controlling any pest or disease of a crop, especially by chemical method should be to see that the pesticides used are least toxic to the major predators in the crop ecosystem. In the case of mite pests also, it is safe to use selective acaricides like propargate or benzoximate which are least harmful to the major predatory groups of mites (Phytoseiidae) and insects. Work enthuse direction needs to be augmented.

Role of kairomones: This is almost a virgin field, much more so in India. Kairomones produced by prey mites serve to attract the predators. Very little or nothing has been done to isolate, identify and synthesize the Kairomones. The role of the host plants of prey mites in the production of Kairomones is yet another area which needs to be investigated, before we make a decision to introduce any predator or get an insight into the behavior of predators on certain plants.

Mass production of predators: Mass production of promising predators, whether mites or insects either in the case of indigenous species or introduced ones becomes necessary. Mass production technology has to be developed in individual cases taking into consideration the feeding habits, whether the predator is monophagous/oligophagous or polyphagous. Monophagous/oligophagous species like *Phytoseiulus persimilis* which feed only on spider mites have to be cultured only on their specific hosts, whereas polyphagous species like *Typhlodromus* and *Amblyseius* which have a wider host range can be cultured on any of their host mites or some even on pollen, and are thus easy to culture and mass produce.

iii. Phytoseiids resistant to pesticide

Resistant strains of phytoseiid mites have to identified in field populations and such resistant mites may be used for mass production. Organophosphate resistant and carbamate resistant strains of certain phytoseiids have been reported abroad. Attempts are also on to breed phytoseiids resistant to certain pesticides in other countries. There is need in this country to identify resistant strains of promising phytoseiids for isolation and further culturing programmes.

iv. Genetic engineering

There is scope for adopting principles of generic engineering in the production of desirable and transgenic phytoseiids for utilisation in the suppression of specific mite pests of crops. There has been no work in this direction in this country. Any single method may not offer a good solutions in the management of a mite pest. An integration of two or more methods may become necessary. It is necessary to investigate the possibilities of utilising an integrated approach in the management of mites pests of crops.

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